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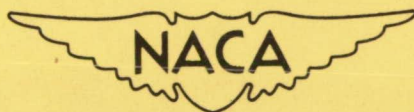
# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2265

NACA VGH RECORDER

By Norman R. Richardson

Langley Aeronautical Laboratory  
Langley Field, Va.



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#### SUMMARY

A compact flight instrument to provide time-history records of airspeed, acceleration, and altitude for continuous periods up to 100 hours has been developed at the Langley Aeronautical Laboratory. This instrument is designated the NACA VGH recorder and was developed primarily for the collection of gust-load data on transport airplanes. Records are obtained on photographic paper moved at sufficient speed to permit statistical determination of gust distribution and also provide, on a condensed time scale, general operational data. The static accuracy of each element in the recorder is within 1 percent of full scale.

#### INTRODUCTION

In connection with gust studies, a need has arisen for a simple and compact airborne instrument that could provide continuous records of airspeed, normal acceleration, and altitude for long periods of operational flight. Whereas the V-G recorder (reference 1) gives an envelope of the maximum accelerations and the airspeeds at which they occur, a continuously recording instrument would give a detailed distribution representing the frequency and intensity of gust accelerations with the associated operating conditions. The instrument had to be light and small, require little maintenance over fairly long periods of time, and provide adequate research accuracy. To fulfill these requirements, the NACA VGH recorder was developed and constructed.

There has been widespread interest on the part of the airlines and the Civil Aeronautics Administration in this instrument and its data. The purpose of this paper is to present, for the interested agencies, a detailed description of the instrument, its characteristics, and its limitations, and to indicate the information it can provide. The considerations that dictated its basic design are also given.

## GENERAL CONSIDERATIONS

The design requirements were based on the specific needs of the National Advisory Committee for Aeronautics for the instrument as a research tool and were correlated with the airlines as regards the problems of installation and operation. The principal requirement of the NACA was reliable recording of the desired functions with sufficient accuracy and in suitable form to make the data useful for research purposes. Of principal concern to the airlines were size, weight, installation difficulties, and reloading interval. Although these requirements generally parallel those set down by the Air Transport Association and Civil Aeronautics Board for flight recorders, the difference in the intended coverage of the instruments should be noted. The ATA-CAB type of recorder is intended to compile data on airline operations and to aid in the determination of accident causes. On the other hand, the NACA recorder was designed specifically as a research instrument and is not intended for large-quantity placement. Accordingly, the instrument design was not compromised to meet the ATA-CAB requirements in detail.

Since the recording method would determine the types of elements used, many systems were studied with regard to the airborne equipment (size, reliability, complexity, and cost) and the data work-up technique (reliability, flexibility, and cost in man-hours and equipment). Among these methods were magnetic-tape recording, variable-area recording on film, and trace recording of the amplitudes on film. The length of recording time desired and the time resolution required precluded the use of variable-area techniques. Recent technical advances in magnetic-tape recording would allow an approach leading to automatic reduction of the record to the statistical form of the data. On the other hand, the trace-recording technique allows visual inspection of the record, a factor which was considered highly advantageous. The advantage of the automatic data reduction possible with the magnetic-tape technique had to balance against the greatly increased cost and complexity of both the airborne and ground equipment. Consideration of these factors and the fact that a system of recording was desired which would afford the necessary flexibility of data work-up resulted in the choice of the trace type of amplitude recording.

The next consideration was the selection of the recording medium which would give the best resolution of the expected acceleration frequencies with a reasonable record speed. Tests showed that the resolution of photographic film or paper was far better than that of the direct-recording types such as the electro-sensitive, pressure-sensitive, or inked papers; also, in general, the direct-recording types require certain stylus pressures with their attendant friction

errors. Since the records were to be returned to the NACA for processing and evaluation, the inherent advantages of an optical recorder were thought to outweigh the disadvantage of having to develop the records. Further weight was given the decision to use optical recording by the fact that certain components of existing NACA instruments could then be used; these components have been developed and improved over a period of years to the degree of accuracy and reliability needed for this application.

It was apparent from the tests that the minimum record speed which would allow the desired time resolution was about 2 feet per hour. At this speed (about 0.007 in. per sec), it is possible, under laboratory conditions, to distinguish peaks of the same amplitude at a rate of two per second and to distinguish peaks of different amplitudes at a rate of five per second. A photographic recording paper, 70 millimeters wide by 200 feet long provides a recording time of about 100 hours. Paper was chosen because it would afford ease of visual inspection; however, film of the same dimensions could be substituted.

Specifically, the final requirements which the instrument was designed to meet were set up as follows:

- (a) Continuous records of airspeed, normal acceleration, and altitude against time with an accuracy within 1 percent of full scale for each element
- (b) Recording time of at least 75 hours per loading with sufficient resolution to permit counting and measurement of individual acceleration peaks
- (c) A remote acceleration transmitter which could be mounted rigidly near the airplane center of gravity regardless of where the recorder might be mounted
- (d) Volume no greater than 1 cubic foot and weight no greater than 25 pounds
- (e) Operation for at least 500 hours without overhaul
- (f) Easy installation and loading
- (g) Automatic operation whenever the airplane is in flight
- (h) Operation from standard aircraft power supply

## INSTRUMENT DESCRIPTION

The instrument consists of three main parts: a base containing the recording elements, a recording drum, and an acceleration transmitter. The base and recording drum together are  $5\frac{3}{4}$  inches wide by  $8\frac{1}{4}$  inches high by 12 inches long, weigh 17 pounds, and are normally shock-mounted in some convenient location such as the radio racks. The remote accelerometer is  $1\frac{5}{8}$  inches wide by  $2\frac{1}{8}$  inches high (not including connectors) by  $7\frac{1}{4}$  inches long, weighs  $2\frac{1}{4}$  pounds, and is rigidly mounted near the airplane center of gravity. Figures 1 and 2 are photographs of the complete instrument and figure 3 is a schematic drawing of the components and optical system.

Each element in the recorder employs a tilting mirror and lens arranged to focus the image of a straight-filament source lamp on the moving record paper. A 0.003-inch-wide aperture slit, adjacent to the moving paper, allows small squares of light to reach the paper so that the records appear as fine lines (fig. 4).

Two cells containing pressure-sensitive diaphragms are connected to the airplane pitot-static lines to measure airspeed and altitude. The diaphragms deflect in proportion to the impressed pressures and their motions are magnified and transmitted to the record paper by the tilting mirror in each cell. Also in each cell is a fixed mirror for providing reference lines on the record. In figure 3 these reference mirrors and lines are omitted for clarity.

A d'Arsonval type of reflecting galvanometer movement is used as the receiver for the electrical signal from the acceleration transmitter. The circuit resistance is such that the galvanometer is damped to about 70 percent of critical.

An electrically wound clockwork mechanism is used as the timer. A mirror on its 1-revolution-per-minute shaft is arranged to sweep a line across part of the paper width and give a 1-minute timing interval.

Other parts of the electrical circuit, including the current-regulating ballast tube for the accelerometer and the necessary resistors, are included in the base. The power-input receptacle, acceleration-transmitter receptacle, and pitot-static connections are mounted on the front face of the instrument. Automatic operation for the instrument is insured by taking its power from some circuit which is always on in flight. The operating power for the recorder is about 20 watts at 24 to 28 volts d-c.

The recording drum contains the paper spools, drive mechanism, and aperture slit. A permanent-magnet motor, used for the drive, has its leads carried to a plug on the underside of the drum which engages a mating receptacle in the base as the drum is installed. Projecting tabs on the drum fit in gibs on the instrument and a small latch secures the drum in position. Since the running parts most subject to wear are in the drum, a check of their condition and any necessary repairs can be made each time a drum is removed for loading; thus the need of removing the recorder base from the aircraft for servicing is reduced.

The acceleration transmitter employs wire strain gages mounted on a cantilever beam. These gages are wired in the form of a Wheatstone bridge, the output voltage of which is proportional to the impressed acceleration. The beam is mounted in a sealed case filled with silicone oil which serves as the damping medium and also protects the gages from moisture. A natural frequency of about 22 cycles per second was considered low enough to isolate it from engine vibrations but high enough to reproduce faithfully the gust accelerations normally encountered. A 25-watt heater and thermoswitch are built into the transmitter to maintain it at constant temperature.

The full-scale deflection for each function is about  $1\frac{3}{4}$  inches. Typical ranges are 0 to 350 miles per hour, -2g to 4g, and sea level to 30,000 feet which cover the usual transport-airplane operation; however, the instrument can be adjusted for other ranges.

#### INSTRUMENT PRECISION

The static accuracy of each element in the recorder is within 1 percent of full scale. The construction of the airspeed and altitude cells is such that the effects of temperature on zeros are negligible. The pressure-sensitive diaphragms in the cells exhibit a sensitivity increase of 1 percent per 50° F temperature increase and vice versa. Although the diaphragm-mirror-shaft combinations have natural frequencies in the range of 50 to 100 cycles per second, the dynamic response of the cells is generally limited by the dimensions of the lines connecting them to the pitot-static pressure sources.

The acceleration transmitter and galvanometer element have very good zero stability with temperature and time. The galvanometer sensitivity is compensated within ±1 percent per 50° F temperature change. Since the transmitter is maintained at a relatively constant temperature by its

heater, the effects of ambient temperature changes on sensitivity and damping are negligible. The natural frequency of the transmitter is about 22 cycles per second and its damping is set at about 0.6 critical. The galvanometer natural frequency is about 8 cycles per second and its damping is set at about 0.7 critical. The response of the combination is flat within about 1 percent up to an impressed sinusoidal frequency of 4.5 cycles as shown in figure 5.

The effects of normal supply-voltage variations on accuracy are negligible. Over the range of 24 to 28 volts, the current-regulating ballast tube will maintain a constant voltage to the accelerometer within 1 percent. Since the timer is an escapement mechanism, wound by a solenoid, the voltage variation will not affect its accuracy. The paper speed varies almost linearly with voltage since the drive is a permanent-magnet direct-current motor, but this variation is not considered serious.

#### DATA APPLICATIONS

The NACA VGH recorder was built and is currently being used principally for the collection of airline operating statistics relative to gust-load problems; however, the instrument presents its data in a manner permitting many operational studies which have airspeed, normal acceleration, and altitude as parameters. Typical analyses that can be made from the records now being obtained are as follows:

For gust research and related airplane loading:

- (1) Evaluation of normal-acceleration increments
- (2) Evaluation of effective gust velocities
- (3) Distribution of normal-acceleration increments and effective gust velocities with airspeed, altitude, or flight condition
- (4) Percentage of total flight miles spent in rough air

For operational studies:

- (1) Airspeed distributions
- (2) Altitude distributions
- (3) Take-off, approach, and landing speeds
- (4) Percentage of flight time in climb and descent

## APPLICATION LIMITS

The accuracy of recording given for the various elements is adequate for the purpose of the statistical study of gust problems. In actual practice, however, the accuracy of the data obtained from this instrument will also be dependent on installation and reading errors. The installation error cannot be assessed in specific terms because it depends upon a given airplane structure and its pitot-static system. Assuming a reading accuracy within  $\pm 0.01$  inch and correction of pitot-static errors by proper calibration, a measured airspeed of 250 miles per hour would have a possible error of  $\pm 2.5$  miles per hour while a speed of 100 miles per hour would be accurate within 5 miles per hour. Similarly, the determination of pressure altitude would be accurate within  $\pm 300$  feet at 20,000 feet and accurate within  $\pm 150$  feet at 2,000 feet. Typical calibration curves for the airspeed and altitude elements are shown in figure 6.

The measurement of acceleration at the center of gravity of an airplane does not necessarily represent the acceleration of an equivalent rigid airplane because of the structural dynamic response. If the acceleration of an equivalent rigid airplane is desired, no accuracy of the measured data can be given since the effects of the dynamic response will depend on a given airplane. This problem remains to be resolved experimentally.

Although the instrument will give a mass of data with little operational effort, there is, of course, limited detail particularly in the acceleration record where the resolution permits the evaluation of effective gust velocity but does not permit the evaluation of the gust structure. Although the record traces are clear, it can be seen in figure 4 that the cramped time scale does not make the details of gust structure visible. For special investigations, this difficulty could be eliminated by increasing the paper speed. Of course, such a change would shorten the reloading interval and reduce the applicability of the instrument for use on the airlines.

## CONCLUDING REMARKS

The NACA VGH recorder satisfies the requirements for which it was designed. It is small enough and light enough to offer no great handling or installation difficulties for the usual types of service airplanes. Probably the principal difficulty is the routing of the pitot-static lines, especially when they must pass through pressurized regions of the aircraft. Access to these lines would likely be the



first consideration in locating the instrument. Routing of the electrical leads from the acceleration transmitter should usually be less difficult. In use the instrument requires the minimum of attention and in normal operation requires only the replacement of recording drums at intervals of about 75 hours of flight operation.

Langley Aeronautical Laboratory  
National Advisory Committee for Aeronautics  
Langley Field, Va., September 26, 1950

#### REFERENCE

1. Taback, Israel: The NACA Oil-Damped V-G Recorder. NACA TN 2194, 1950.

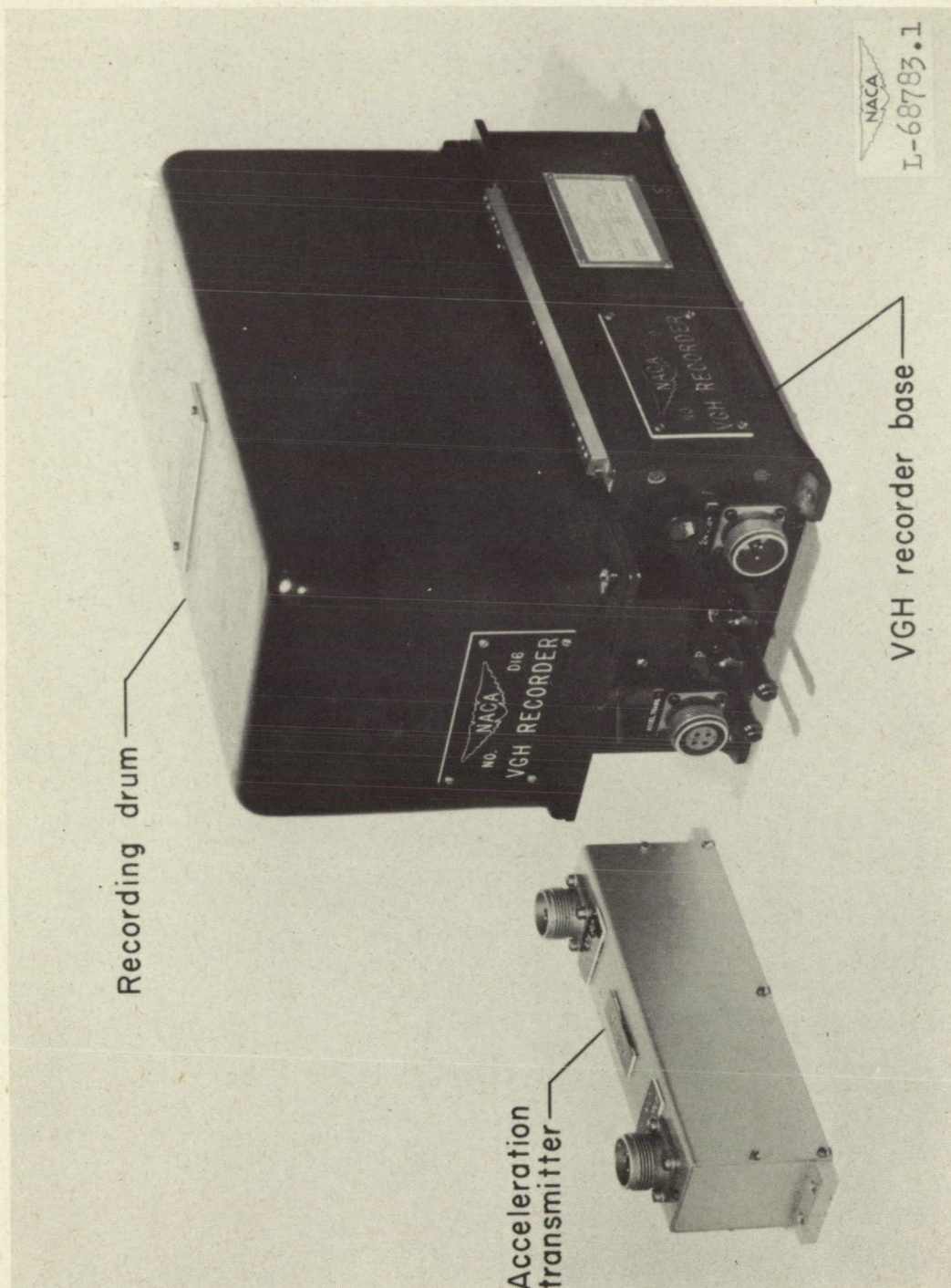


Figure 1.- NACA VGH recorder.

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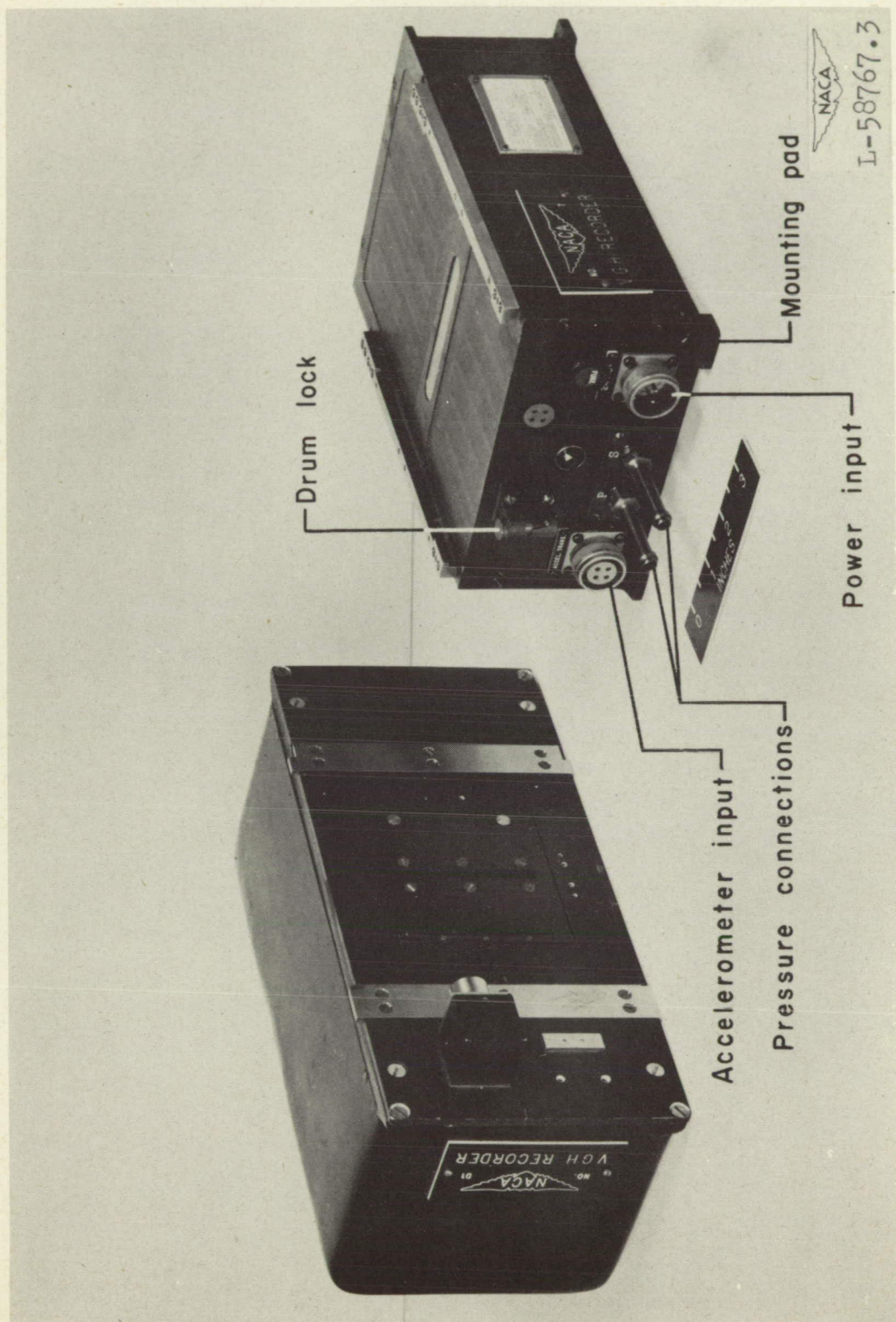


Figure 2.- NACA VGH recorder with recording drum removed.

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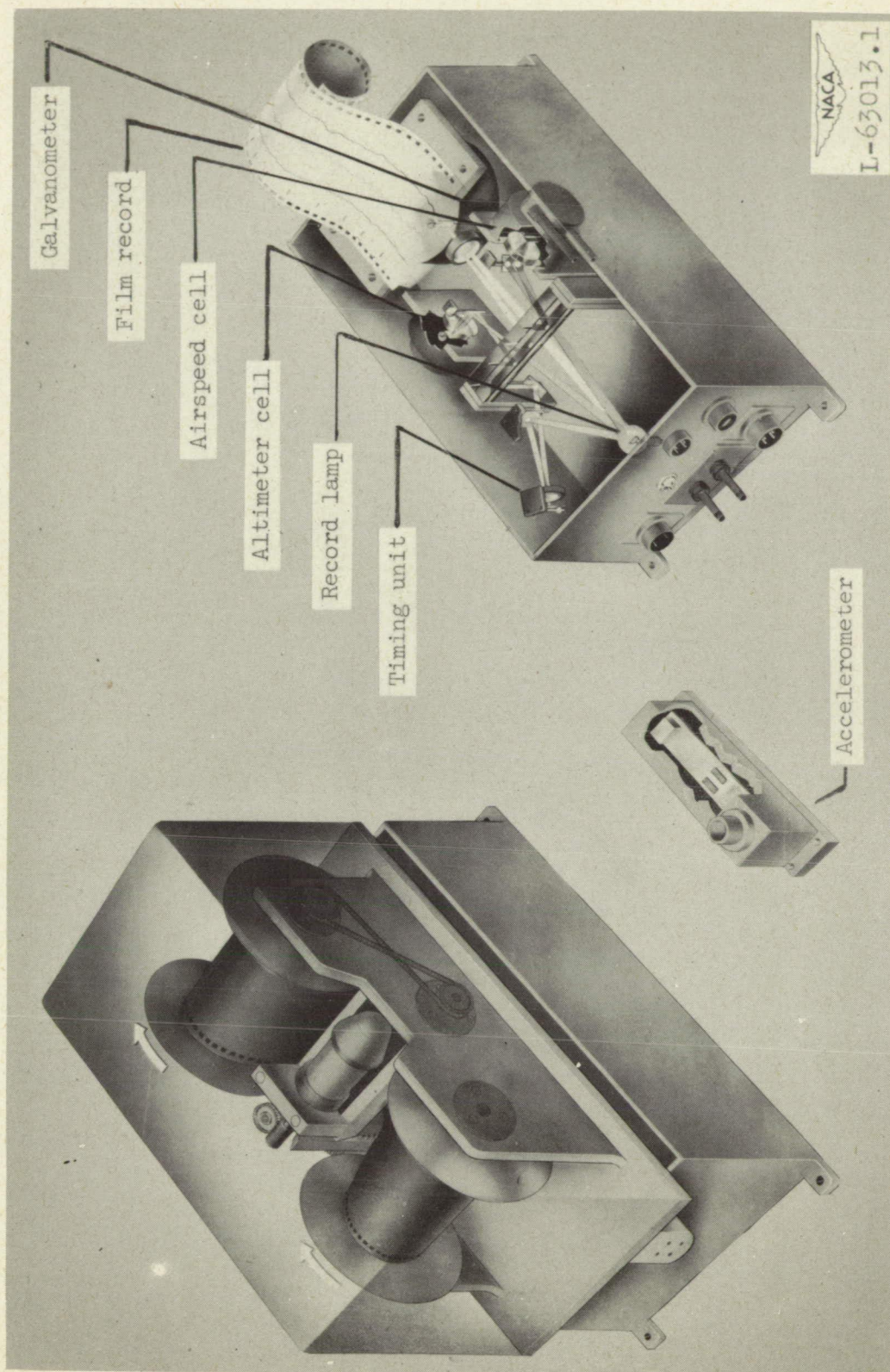
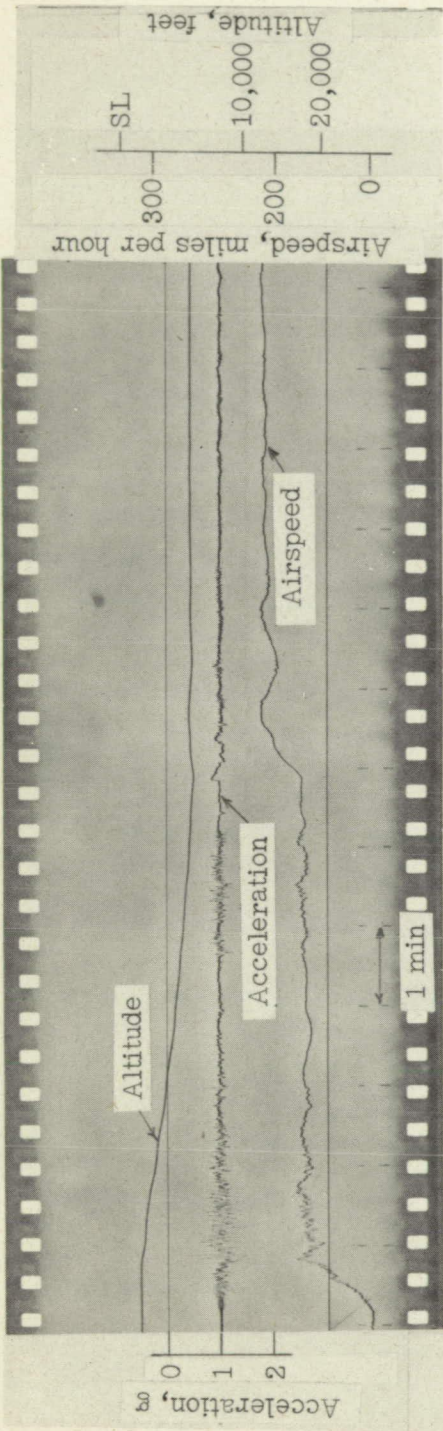


Figure 3.- Schematic drawing of VGH recorder.

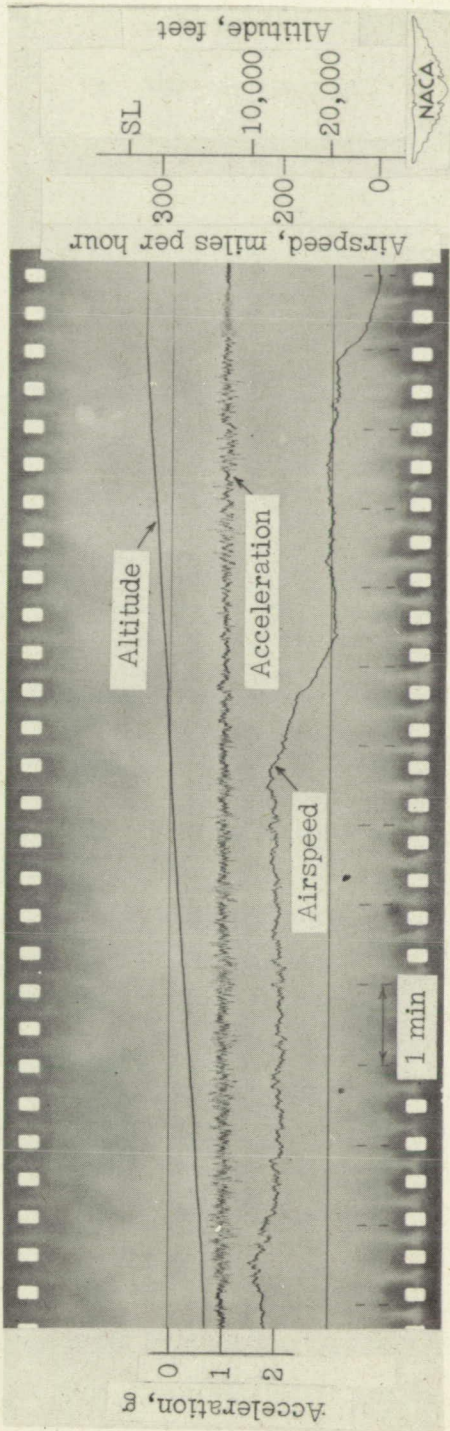
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(a) Take-off and climb.



(b) Descent and landing.

Figure 4.- Reproduction of VGH records from transport operation.



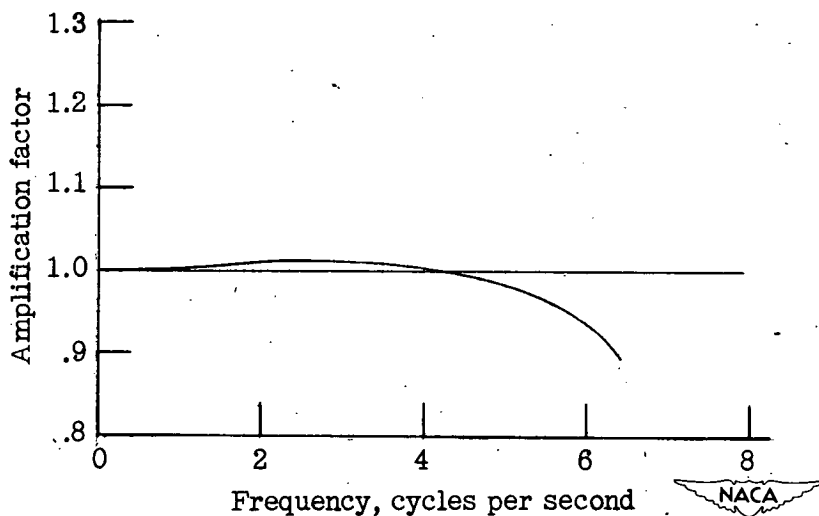


Figure 5.- Typical response of VGH recorder acceleration channel to impressed sine-wave acceleration.

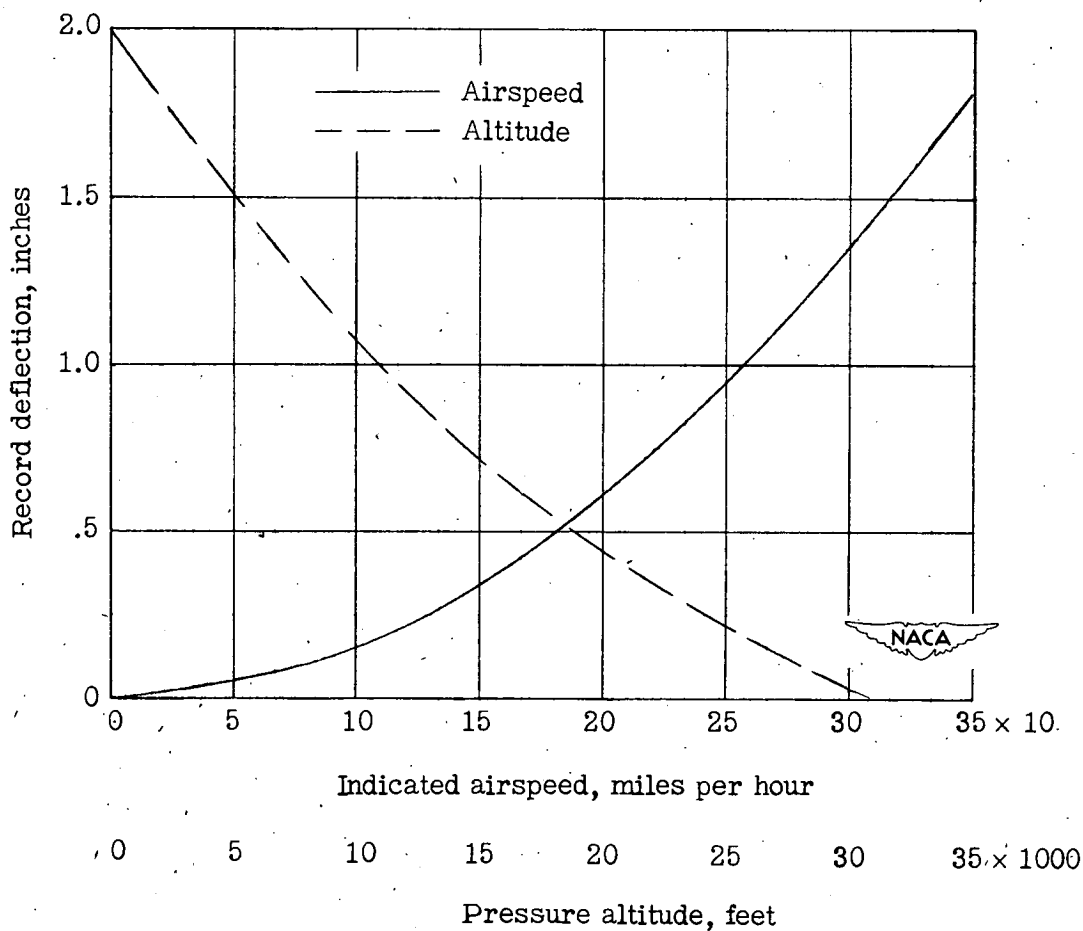


Figure 6.- Typical VGH recorder airspeed and altitude calibrations.